

# The Effect and Safety of Short-Term Creatine Supplementation on Performance of Push-Ups

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The effects of short-term oral creatine (Cr) supplementation on exercise performance and on blood pressure and renal function were assessed. Thirty-five healthy, active duty, U.S. Army volunteers (20 men and 15 women; age, 22–36 years) at Fort Sam Houston, Texas, supplemented their diet for 7 days with 20 g/day of either Cr or taurine (as placebo). There was no significant difference in 2-minute push-up counts between the Cr and taurine groups from before to after supplementation ( $p = 0.437$ ; power = 0.98). The Cr group demonstrated a significant increase in serum creatinine levels ( $p < 0.001$ ), compared with the taurine group, and this increase could be misinterpreted as impairment of renal function. No adverse changes in blood pressure, body composition, weight, or serum Cr phosphokinase levels were observed. We conclude that short-term Cr supplementation appears to be safe but does not enhance push-up performance.

## Introduction

The U.S. Army uses a 2-minute push-up count to assess soldiers' upper body strength and endurance in the Army Physical Fitness Test (APFT).<sup>1</sup> Performance on the APFT can enhance or negatively affect a soldier's career. Therefore, there is significant motivation to improve performance. There is anecdotal evidence that some soldiers use over-the-counter performance enhancers, including creatine (Cr) supplements, in an attempt to improve performance on the APFT.

Cr is an amino acid that is found in high concentrations in meat, fish, and poultry. It is a popular commercial dietary supplement because of its ergogenic properties.<sup>2</sup> Physiologically, Cr is stored in the cytosol of muscle cells as phosphocreatine (PCr)<sup>3</sup> and is important in short-term adenosine triphosphate (ATP) production for muscle contraction. Ingestion of 20 g/day Cr for ≥5 days has been shown to effectively increase total intramuscular Cr and PCr levels in skeletal muscle.<sup>2,4–9</sup>

Cr supplementation has been shown to be effective in improving short-duration, high-intensity, physical activities involving the upper extremities, such as bench presses, swimming, and rowing.<sup>10–18</sup> Previous research demonstrated that high-intensity, upper extremity exercise in repeated bouts and for durations of <60 seconds is enhanced by Cr supplementation. However, there is little evidence to support the use of Cr for durations of >60 seconds.<sup>2,3</sup> To our knowledge, there has been no study of the effect of Cr supplementation on short-duration push-up performance. We hypothesized that Cr supplementation would have beneficial effects on push-up performance in the APFT.

Despite the potential benefits of Cr supplementation, a diet rich in amino acids may pose a risk to renal function,<sup>19</sup> particularly for those with impaired renal function.<sup>20,21</sup> The magnitude of Cr ingestion required to improve performance has raised concerns about the safety of supplementation. In fact, Cr supplementation has been associated with kidney dysfunction in subjects with a history of kidney disease.<sup>22,23</sup> Research on short-term and long-term Cr supplementation has not demonstrated any adverse effects on kidney function in healthy adults.<sup>24–30</sup> In addition, few studies have investigated other potential health effects of Cr supplementation, such as changes in blood pressure and muscle enzyme levels.<sup>31,32</sup> Given the relatively few studies on the safety of Cr supplementation and the lack of information regarding Cr supplementation and push-up performance, the present study was performed to determine whether short-term Cr supplementation affects push-up performance and to further assess the safety of oral supplementation for healthy soldiers.

## Methods

### Subjects

Thirty-five healthy subjects from the U.S. Army active duty population at Fort Sam Houston, Texas, voluntarily enrolled in the study. Subjects were screened for inclusion and exclusion criteria 7 to 14 days before data collection. Inclusion criteria were age (22–36 years) and maximal-effort APFT push-up performance of 12 push-ups from the minimum needed to pass. Exclusion criteria, identified with a medical history questionnaire, included history of kidney disease, current kidney dysfunction (defined as Cockcroft-Gault glomerular filtration rate [CG-GFR] of <80 mL/min for men and <70 mL/min for women),<sup>33</sup> significant malabsorptive gastrointestinal conditions, preexisting muscular disease, medical disability prohibiting push-up performance, and use of performance-enhancing supplements within 6 weeks before data collection. In addition,

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The opinions and assertions contained within this manuscript are those of the authors and are not to be construed as official policy of the U.S. Department of the Army or the Department of Defense.

This manuscript was received for review in November 2005. The revised manuscript was accepted for publication in July 2006.

<b>Report Documentation Page</b>			Form Approved OMB No. 0704-0188	
<p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p>				
1. REPORT DATE <b>01 MAR 2007</b>	2. REPORT TYPE <b>N/A</b>	3. DATES COVERED <b>-</b>		
<b>4. TITLE AND SUBTITLE</b> <b>The effect and safety of short-term creatine supplementation on performance of push-ups</b>			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
<b>6. AUTHOR(S)</b> <b>Armentano M. J., Brenner A. K., Hedman T. L., Solomon Z. T., Chavez J., Kemper G. B., Salzberg D., Battafarano D. F., Christie D. S.,</b>			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> <b>United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX 78234</b>			8. PERFORMING ORGANIZATION REPORT NUMBER	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
<b>12. DISTRIBUTION/AVAILABILITY STATEMENT</b> <b>Approved for public release, distribution unlimited</b>				
<b>13. SUPPLEMENTARY NOTES</b>				
<b>14. ABSTRACT</b>				
<b>15. SUBJECT TERMS</b>				
<b>16. SECURITY CLASSIFICATION OF:</b> a. REPORT <b>unclassified</b>			<b>17. LIMITATION OF ABSTRACT</b> <b>SAR</b>	<b>18. NUMBER OF PAGES</b> <b>7</b>
b. ABSTRACT <b>unclassified</b>			c. THIS PAGE <b>unclassified</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>

women were excluded because of pregnancy (identified with a positive pregnancy test). Eligible subjects were informed of the experimental procedures, voluntarily signed the detailed consent form, and were randomly assigned to either the Cr or taurine group. The research protocol and informed consent form were reviewed and approved by the institutional review board and clinical investigation committee at Brooke Army Medical Center (Fort Sam Houston, Texas).

### Supplementation

Based on group assignment, each subject received a 7-day supply of either 5 g of Cr or 5 g of taurine, mixed with 16 g of sucrose, in 125-mL resealable cups. High-pressure liquid chromatography analysis of the Cr (Research Triangle Laboratories, Raleigh, North Carolina) indicated  $98.9 \pm 2\%$  purity. Cr and taurine supplements were visually indistinguishable and similar in taste and smell.

Starting on day 7, subjects ingested four 5-g supplements mixed with 250 mL of fruit punch, one with each meal and one with a snack, for a total of 20 g of supplement per day. Subjects were instructed to maintain their normal activity level and diet. Each subject was given a dietary food record with instructions to record food and beverage intake on days 1, 11, 12, 13, and 14.

### Experimental Design

This was a double-blind, placebo-controlled study. Five dependent variables were investigated, that is, number of push-ups performed in 2 minutes, serum creatinine (Scrn) level, CG-GFR, diastolic blood pressure (DBP), and serum Cr phosphokinase (CPK) level.

### Data Collection Protocol

Pre- and postsupplementation assessments were conducted between 5:00 a.m. and 7:30 a.m. on days 2 and 15. Assessments included (a) height and weight measurements with a standard height and weight scale (DETECTO model 439; Cardinal, Webb City, Missouri) and blood pressure measurements with an electronic sphygmomanometer (Colin Pressmate; Colin, Komaki City, Japan); (b) body composition analysis with a bioelectric impedance analyzer<sup>34,35</sup> (model 310; Biodynamics, Seattle, Washington); (c) 2-minute push-up performance; and (d) CPK and Scrn levels.

### Push-Up Performance Measurement

Subjects were instructed on proper push-up form, according to Army Field Manual 21-20, before push-up performance measurements on days 2 and 15. A digital timer was used to measure the 2-minute push-up performance. One on-site grader counted the push-ups performed by each subject during the data collections.

### Push-Up Counting Reliability

At the time of this study, no data existed in the literature regarding push-up counting reliability. Therefore, we needed to determine whether push-up performance could be determined reliably. To establish push-up counting reliability, pre- and postsupplementation performances were recorded with a VHS video camera. The recordings were used to establish interrater and intrarater push-up counting reliability. Camera placement rel-

ative to subject position was established to mimic the view of the APFT grader. The on-site grader and two additional graders scored the push-up performances from the videotapes. Pre-supplementation push-up performances were scored from the videotape by each of the three graders independently on two different occasions separated by  $\geq 7$  days. Postsupplementation push-up performances were also scored by each of the three graders independently on two different occasions separated by  $\geq 7$  days, with scoring conducted  $\geq 7$  days after the graders completed their last presupplementation push-up performance.

### Blood Collection Procedure

Blood samples were obtained from each subject's antecubital vein, by using standard phlebotomy procedures, on days 2 and 15. An 8.5-mL serum-separation tube (Vacutainer, BD Biosciences, Franklin Lakes, New Jersey) was used to collect blood samples for analysis of Scrn and CPK levels at the Brooke Army Medical Center clinical pathology laboratory, using standard procedures for these analyses. After collection, all samples were refrigerated and immediately transported to the laboratory.

### Urine Specimen Collection

The 24-hour urine specimen collections were completed on the morning of days 2 and 15, just before pre- and postsupplementation data collections (i.e., the 24-hour urine specimen collections were begun after the first morning urine void on days 1 and 14 and continued over 24 hours to include the first morning urine collection on days 2 and 15). Urine pregnancy tests (qualitative  $\beta$  human chorionic gonadotropin tests) were conducted for female subjects from both pre- and postsupplementation urine collections.

### Statistical Analyses

Independent sample *t* test or  $\chi^2$  analyses were conducted for all descriptive variables. The official push-up count used for data analysis was an average of the on-site grader's live and two video graders' push-up counts for each subject. Push-up performance, Scrn level, CPK level, DBP, and CG-GFR were analyzed with a  $2 \times 2 \times 2$  (group  $\times$  time  $\times$  gender), repeated-measures, multivariate analysis of variance, using SPSS for Windows software (version 8.0; SPSS, Chicago, Illinois). Statistical significance levels for the multivariate analysis of variance and descriptive statistics were set at  $p < 0.05$ . Univariate analyses were conducted for push-up performance, Scrn level, CPK level, DBP, and CG-GFR. The level of statistical significance for the univariate analyses was Bonferroni-corrected to  $p < 0.01$ . Tukey's honestly significant difference (HSD) post hoc procedures were performed on the group means to examine significant group  $\times$  time interactions. Power analyses and push-up counting reliability were determined by using SPSS software. Push-up performance scoring intrarater reliability for the on-site rater and interrater reliability for all three raters were determined by using intraclass correlation coefficient (ICC) models of ICC(3,1) and ICC(2,1), respectively. Data from the dietary food records were reduced with Nutritionist 4 software (Herst Corp., Salem, Oregon) and were analyzed with independent-samples *t* tests by using SPSS software.

## Results

Thirty-five volunteers participated in the study. Eighteen subjects were in the Cr group (10 men and 8 women) and 17 subjects were in the taurine group (10 men and 7 women). There were no significant differences between the Cr and taurine groups in gender, age, height, weight, lean body weight, percentage of body fat, total body water, or percentage of body water (Table I).

### Push-Up Rating Reliability

The on-site grader's intrarater reliability for presupplementation ratings was  $ICC(3,1) = 0.969$  ( $F$  ratio = 97.13), and that for postsupplementation ratings was  $ICC(3,1) = 0.950$  ( $F$  ratio = 58.18). The  $F$  ratios for both exceeded the critical  $F$  ratio of 1.65. Interrater reliability among all three raters was  $ICC(2,1) = 0.884$  ( $F$  ratio = 21.96) for presupplementation ratings and  $ICC(2,1) = 0.870$  ( $F$  ratio = 22.37) for postsupplementation ratings. The  $F$  ratios for both exceeded the critical  $F$  ratio of 1.50.

### Performance

There was no significant difference in 2-minute push-up test performance between the Cr and taurine groups from before supplementation to after supplementation ( $p = 0.437$ ). Presupplementation push-up counts for the Cr and taurine groups averaged  $30.06 \pm 10.69$  and  $32.47 \pm 14.29$  push-ups, respectively. Mean postsupplementation push-up counts for the Cr and taurine groups were  $32.83 \pm 11.69$  and  $33.82 \pm 13.58$  push-ups, respectively. Power was 0.98, based on a predetermined meaningful effect size of five push-ups.

### Health Factors

The Cr group demonstrated a significant increase in Scrn levels ( $p < 0.001$ ) after supplementation, compared with the taurine group. Presupplementation Scrn values for the Cr and taurine groups were  $0.9222 \pm 0.1166$  and  $0.9118 \pm 0.1111$  mg/dL, respectively. Postsupplementation Scrn values for the Cr and taurine groups were  $1.0833 \pm 0.2007$  and  $0.9176 \pm 0.1074$  mg/dL, respectively. The Cr group also demonstrated a significant decrease in CG-GFR after supplementation, compared with the taurine group ( $p < 0.001$ ). Presupplementation CG-GFR values for the Cr and taurine groups were  $115.52 \pm 21.63$  and  $122.48 \pm 25.68$  mL/min, respectively. Postsupplementation CG-GFR values for the Cr and taurine groups were  $100.34 \pm 21.81$  and  $121.69 \pm 26.10$  mL/min, respectively. The results of Tukey's HSD post hoc test for Scrn and CG-GFR are presented in Tables II and III, respectively. Despite randomization procedures, a significant difference in CG-GFR between the two groups existed before supplementation. However, the presupplementation CG-GFR values for both groups were within the normal clinical range. In relation to DBP as a measure of hypertension, no significant difference existed between Cr and taurine groups from before to after supplementation ( $p = 0.753$ ). Presupplementation DBP values for the Cr and taurine groups were  $67.3 \pm 9.6$  and  $66.7 \pm 6.6$  mm Hg, respectively. Postsupplementation DBP values for the Cr and taurine groups were  $70.0 \pm 8.7$  and  $69.0 \pm 9.1$  mm Hg, respectively. Additionally, no significant difference in CPK levels existed between the Cr and taurine groups from before to after supplementation ( $p = 0.520$ ).

TABLE I  
DESCRIPTIVE STATISTICS

	Gender	Age (years)	Height (cm)	Weight (kg)	Lean Body Weight (kg)	Body Fat (%)	Body Water (L)	Body Water (%)	Systolic Blood Pressure (mm Hg)	DBP (mm Hg)	CPK (IU/L)
Before supplementation											
Cr	10 M/8 F	27.38 ± 4.74	173.32 ± 7.76	72.80 ± 9.39	60.05 ± 7.89	17.47 ± 4.14	41.46 ± 6.25	66.52 ± 6.70	124.78 ± 11.13	67.33 ± 9.57	195.72 ± 181.25
Taurine	10 M/7 F	25.94 ± 2.53	173.05 ± 11.26	74.81 ± 13.94	61.97 ± 11.25	17.57 ± 5.18	43.18 ± 8.53	68.21 ± 3.85	121.53 ± 8.50	66.71 ± 6.59	171.76 ± 106.12
<i>p</i> value		0.845 <sup>a</sup>	0.267 <sup>b</sup>	0.933 <sup>b</sup>	0.619 <sup>b</sup>	0.560 <sup>b</sup>	0.951 <sup>b</sup>	0.498 <sup>b</sup>	0.341 <sup>b</sup>	0.824 <sup>b</sup>	0.639 <sup>b</sup>
After supplementation											
Cr	73.62 ± 9.32	60.69 ± 7.99	17.56 ± 4.43	39.88 ± 10.92	66.49 ± 7.05	126.78 ± 10.38	70.00 ± 8.65	483.89 ± 1.330.31			
Taurine	74.71 ± 14.06	60.93 ± 12.15	18.52 ± 4.65	42.16 ± 8.96	67.31 ± 4.57	127.94 ± 11.18	69.00 ± 9.12	256.12 ± 277.94			
<i>p</i>		0.788 <sup>b</sup>	0.943 <sup>b</sup>	0.553 <sup>b</sup>	0.505 <sup>b</sup>	0.689 <sup>b</sup>	0.752 <sup>b</sup>	0.741 <sup>b</sup>	0.494 <sup>b</sup>		

<sup>a</sup>  $\chi^2$  analysis.

<sup>b</sup> Independent samples' *t* test.

TABLE II  
TUKEY'S HSD FOR SERUM CR LEVELS

Comparison	Mean HSD
Cr pre vs. Cr post	0.1611 <sup>a</sup>
Taurine pre vs. taurine post	0.0058
Cr pre vs. taurine pre	0.0104
Cr post vs. taurine post	0.1657 <sup>a</sup>

r (number of means) = 2;  $df_e$  = 31; mean square error = 0.004247; critical HSD = 0.0457.

<sup>a</sup> Significant mean HSD.

TABLE III  
TUKEY'S HSD FOR CG-GFR

Comparison	Mean HSD
Cr pre vs. Cr post	15.18 <sup>a</sup>
Taurine pre vs. taurine post	0.79
Cr pre vs. taurine pre	6.96 <sup>a</sup>
Cr post vs. taurine post	21.35 <sup>a</sup>

r = 2;  $df$  = 31; mean square error = 40.45; critical HSD = 4.46.

<sup>a</sup> Significant mean HSD.

Presupplementation CPK values for the Cr and taurine groups were  $195.72 \pm 181.25$  and  $171.76 \pm 106.12$  IU/L, respectively. Postsupplementation CPK values for the Cr and taurine groups were  $483.89 \pm 1,330.31$  and  $256.12 \pm 277.94$  IU/L, respectively. Two subjects from the Cr supplement group were noted to have elevated CPK levels (5,797 and 1,106 IU/L). After careful medical evaluation, it was determined that both subjects had elevated CPK levels in association with significant physical activity (10-km race and softball, respectively) during hot weather 1 day before phlebotomy. Follow-up CPK levels were normal when checked within 1 week after the noted elevation.

#### Supplementation Compliance and Dietary Consumption Data

Supplementation compliance was determined through both analysis of Scrn and mandatory return of all supplement containers. Because a portion of ingested Cr is converted to creatinine, an increase in Cr supplementation causes an increase in Scrn levels. The Cr group's significantly elevated postsupplementation Scrn levels indicated supplementation compliance. In addition, only three of the 18 subjects from the Cr group failed to return all empty supplement containers. Two of these subjects failed to return one container and one subject failed to return two containers. No significant difference existed between the Cr and taurine groups in protein consumption during the supplementation period ( $p = 0.904$ ). The Cr group and taurine groups ingested  $1.24 \pm 0.55$  and  $1.28 \pm 1.04$  g/kg, respectively.

#### Discussion

The results of our study indicated that 7 days of Cr supplementation at 20 g/day did not improve 2-minute push-up performance. Previous research demonstrated that oral Cr supplementation at 20 g/day for  $\geq 5$  days improved short-duration, high-intensity, upper extremity, exercise performance, such as bench presses, swimming, and rowing.<sup>10-18</sup> The most plausible explanation for our failure to see improved performance might

be related to the 2-minute duration of the push-up performance test. Previous research suggested that Cr supplementation provides the most benefit in maximal-intensity exercise lasting <60 seconds.<sup>2,3</sup> In maximal-intensity exercise lasting >60 seconds, glycolysis becomes the primary source of ATP and the contribution of PCr in ATP production is greatly diminished.<sup>36</sup> Analysis of the first 1 minute of push-ups indicated that Cr supplementation also did not significantly affect performance during this shorter time interval, which supports the idea that Cr supplementation enhances strength performance but not endurance.

Another possible factor affecting the push-up performance result is a "ceiling effect," i.e., perhaps the subjects were already doing as many push-ups as humanly possible and no further increase was possible. However, the inclusion criterion for our subjects that they had to be doing no more than 12 push-ups from the minimal passing number eliminated this possibility, because of the large range between the minimum required to pass and the maximal push-up score for the age groups included in this study. For men, the minimal number of push-ups required to pass varies from 36 to 40 push-ups, and the number of push-ups required to receive the maximal score is 75 to 77 push-ups. For women, the minimal number of push-ups required to pass varies from 15 to 17 push-ups, and the number of push-ups required to receive the maximal score is between 45 and 50 push-ups.<sup>1</sup> Therefore, there was substantial room for improvement during the course of the study and no evidence of a ceiling effect.

This study supports previous observations for successful Cr supplementation.<sup>2,4,5,8,9,37,38</sup> The accepted Cr supplementation regimen calls for ingestion of  $\geq 20$  g/day for 5 days.<sup>3</sup> Because ~2% of Cr during protein loading is converted to creatinine,<sup>39</sup> increased Scrn levels were anticipated for individuals supplementing with Cr. In fact, the Cr group demonstrated a significant Scrn increase, which indicated plasma saturation with Cr and thus an effective protocol.

It has been suggested that a diet rich in amino acids may pose a risk to kidney function.<sup>19-21</sup> Ingesting large amounts of amino acids increases production of nitrogenous waste and thereby may induce some degree of kidney compromise. Repetitive ingestion of large quantities of amino acids has been hypothesized as a cause of kidney dysfunction.<sup>40</sup> Taurine, an amino acid that is primarily excreted by the kidney, was used as the control agent in this study because at high doses it does not induce kidney dysfunction<sup>41</sup> and it has not been shown to have a significant ergogenic effect. Previous research on Cr indicated that supplementation does not adversely affect kidney function.<sup>25-30,42</sup> However, our study demonstrated a decrease in estimated glomerular filtration rate (GFR) (i.e., CG-GFR). These results are questionable because of the small sample size and questionable supplementation protocol. Estimation of GFR by any formula presumes that the system is in steady state. Because of active supplementation, this might not have been the case, thereby invalidating the CG-GFR results. Additionally, because CG-GFR calculations use a regression formula based on age, weight, and Scrn concentration<sup>33</sup> and the only variable that changes over a 15-day period is Scrn level, estimated GFR is always inversely proportional to Scrn. Because Cr is converted to Scrn, one

would expect CG-GFR to decrease with Cr supplementation, without necessarily affecting true endogenous GFR. Ideally, 24-hour urine collections would have corrected for this, but too few subjects were able to complete the 24-hour urine collection, because of technical errors.

Subjects in both the Cr and taurine groups demonstrated no significant changes in DBP or CPK from before to after supplementation. This result supports the findings of other studies on the effect of Cr supplementation on cardiovascular and muscular function.<sup>31,32,43</sup>

## Conclusions

Many athletes and soldiers consider oral supplements to enhance their performance. Seven days of Cr supplementation does not increase 2-minute push-up performance. Cr supplementation does cause a normal physiological increase in Scrn levels, and this increase may be confused with kidney compromise if a physician is unaware that a patient is supplementing with Cr.

Our study reveals that short-term Cr supplementation does not improve high-intensity, body weight-resistance, upper extremity exercise lasting >60 seconds. Additionally, the results of the present study support the currently accepted idea that short-term Cr supplementation appears to be safe, without any deleterious health effects such as changes in blood pressure or kidney function.

## Acknowledgments

We thank the subjects who participated and the following individuals who contributed to the study: COL Stephen Allison, USA (Ret.); MSG Mark Kenyon, USA; SFC Shauntel Thompson, USA; COL William Boisvert, USA; and the Department of Clinical Pathology, Brooke Army Medical Center.

This study was funded by the Department of Clinical Investigation, Brooke Army Medical Center (Fort Sam Houston, Texas). The U.S. Army-Baylor University Graduate Program in Physical Therapy independently collected, analyzed, and interpreted data from this study and has no financial interest in the outcome of results reported.

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